Space Technology Research Grants

Construction of Predictive Uncertainty Quantification Framework to the Extrapolation of TPS Arc-Jet Experiment Data to Flight Conditions

Completed Technology Project (2017 - 2021)

Project Introduction

Objective 1.1 of the 2014 Strategic Plan states that NASA's efforts will continue to be to "Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration." Although NASA's safe delivery of the Curiosity rover to the surface of Mars proved the organization's ability to transport unmanned cargo, significant progress must be made prior to accomplishing the same feat with human astronauts onboard. Namely the understanding of the physical processes and ability to protect the space vehicle from the harsh conditions encountered in hypersonic atmosphere entries must be expanded upon. Researchers depend on computational models and ground facility scale tests to study the performance of thermal protection systems [TPS] that protect space vehicles from the high temperature gases involved. However, the conditions reproduced at current complexes such as plasma flow wind tunnels cannot match simultaneously all of the actual flight conditions. More importantly, the aerothermal environment on the entire vehicle cannot be reproduced. It can only be approximated at few points such as the stagnation line. The need for proper uncertainty quantification and propagation of, including but not limited to, epistemic uncertainty of systems is outlined in section 11.3.6 of TA-11 as well as validation of modeling tools in section 11.3.8.1 of TA-11. The proposed work focuses on the development of a stochastic model for enhancing the ability to extrapolate arc-jet facility TPS data to flight conditions as well as validation and uncertainty quantification through Bayesian methods. It has been shown that even for small probes, radiative heating constitutes 10% of the total heat flux [Chazot]. However, current plasma flow wind tunnel methodologies are unable to reproduce the effects of the radiative processes or the Mach number of the flow experienced in hypersonic Mars return atmosphere entries. By applying a stochastic model to arc-jet facility data that accounts for the inability to recreate all flight conditions at the stagnation point, and propagation and quantification of uncertainty of the system, the confidence with which the results can be extrapolated will be increased and limitations made known. The statistical approach to model validation will be tested using EFT1 flight data. The construction of the stochastic model and planned uncertainty quantification and validation treatments will help increase the compatibility of ground facility results with flight conditions.

Anticipated Benefits

By applying a stochastic model to arc-jet facility data that accounts for the inability to recreate all flight conditions at the stagnation point, and propagation and quantification of uncertainty of the system, the confidence with which the results can be extrapolated will be increased and limitations made known. The statistical approach to model validation will be tested using EFT1 flight data. The construction of the stochastic model and planned uncertainty quantification and validation treatments will help increase the

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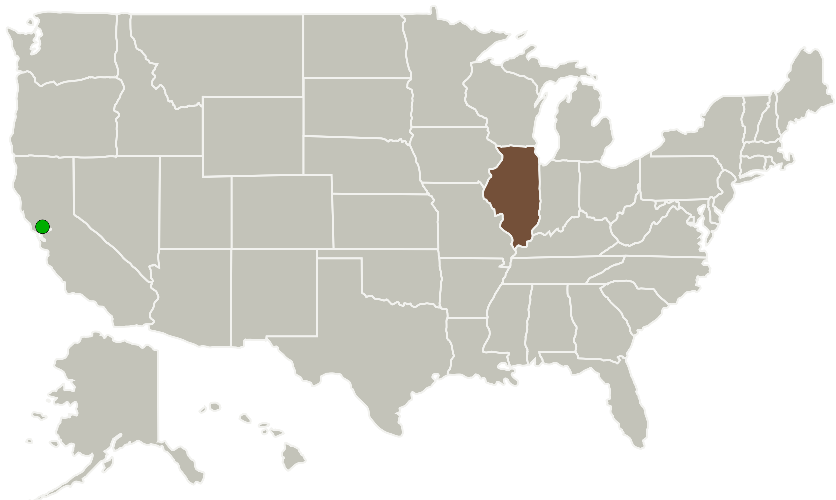
compatibility of ground facility results with flight conditions.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Illinois at Urbana-Champaign	Lead Organization	Academia	Urbana, Illinois
Ames Research Center(ARC)	Supporting Organization	NASA Center	Moffett Field, California

Primary U.S. Work Locations
Illinois

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Illinois at Urbana-Champaign

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

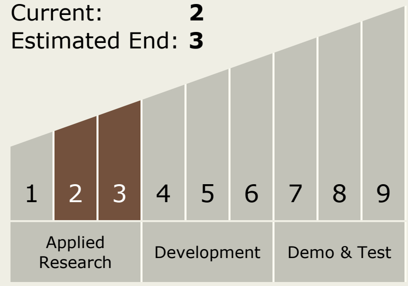
Marco Panesi

Co-Investigator:

Przemyslaw Rostkowski

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  - └─ TX09.4 Vehicle Systems
    - └─ TX09.4.5 Modeling and Simulation for EDL

Target Destination

Foundational Knowledge